Assessment of Gender Priority on Groundwater Utilization in Northwestern Bangladesh

Md. Asaduzzaman
Graduate Student, Department of Rural Sociology, Bangladesh Agricultural University, Mymensingh, Bangladesh
Md. Wakilur Rahman*
Professor, Department of Rural Sociology, Bangladesh Agricultural University, Mymensingh, Bangladesh
Md. Salauddin Palash
Professor, Department of Agribusiness and Marketing, Bangladesh Agricultural University, Mymensingh, Bangladesh
Shokhrukh–Mirzo Jalilov
Senior Research Scientists, Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
**Corresponding author:* wakilrsbau@gmail.com
https://sriopenjournals.com/index.php/forestry_agricultural_review/index

Doi: https://doi.org/10.47285/far.v1i2.36

Citation: Asaduzzaman, M., Rahman, M. W., Palash, M. S. & Jalilov, S. M. (2020). Assessment of Gender Priority on Groundwater Utilization in Northwestern Bangladesh, *Forestry & Agriculture Review*, 1(2), 13-28. Doi: https://doi.org/10.47285/far.v1i2.36

Research Article

Abstract

The present study was undertaken to find out gender-specific priorities in groundwater utilization for crop production and domestic uses, and also to identify various problems and constraints faced in groundwater utilization. A total of 60 farm households were selected randomly for empirical investigation from two northwestern districts of Bangladesh. Among these selected households, both husband and wife were interviewed separately. Both descriptive and econometric (logistic regression) analyses were performed. Groundwater is the main source of irrigation and household water and it is supplied by both public and private enterprises. The availability of water is scarce in the study location hence people use irrigation water for most of their domestic activities. Barind Multipurpose Development Authority (state-run) operated tube wells that contributed 87% of the domestic water uses in the study area. Logistic regression results confirm that priorities of groundwater utilization vary across gender. Females have a greater preference for domestic uses of groundwater while males have a preference for crop irrigation. One of the major factors of preference variation is that female has to spent a good amount of time in fetching water for domestic uses. Water management policies should consider these utilization preferences to avoid extra burden on women in fetching water from away. The study suggests better institutional arrangements for groundwater availability for crop production and domestic uses towards ensuring food security and health benefits.

Keywords: Groundwater, gender, priority, logistic regression.

1. Introduction

Bangladesh has a unique geography with the largest delta sloping gently south and southeastward (Amin et al., 2003) to meet the longest seashore in the world. This largest delta is

formed by the Ganges, the Brahmaputra, and the Meghna (GBM) river system with about 700 rivers, canals, and streams with a total length of approximately 24,000 km (World Bank, 2016). Despite having 700 rivers, canals, and streams, agricultural production is mostly groundwater dependent. About 79% of cultivated land is irrigated by groundwater and the remaining by surface water (Qureshi et al., 2015). Rivers and canals become dry during the dry season (January-May) and make the people completely dependent on groundwater for irrigation (Shahid and Behrawan, 2008). The Northwestern (NW) Bangladesh supplies about 35% of irrigated *boro* rice and 60% of the wheat (Mainuddin et al., 2014) as the main contributor to self-sufficiency in food production with a total cultivable area of about 1.34 million acres (BBS, 2019). About 85% of the land is under groundwater coverage in NW regions (Mainuddin et al., 2014) while the national average is 80% (Rahman and Parvin, 2009). In fact, groundwater irrigation has been the most dramatic development in Bangladesh agriculture during the past 30 years and availability of groundwater for irrigation has contributed to manifold increases in crop productivity of Bangladesh particularly in the NW region (Dey et al., 2013). However, over dependency on groundwater is causing severe groundwater depletion especially in the NW region. Increasing population, food insecurity, growing economics, and poor water management are putting unprecedented pressure (UNCSD, 2012) on the groundwater level. Besides irrigation, groundwater is also used extensively for domestic purposes. As groundwater depletion is observed in some parts of northwestern Bangladesh, both public and private enterprises have extended piped water services for domestic uses. It is noted that irrigation water required for only dry-season but for domestic purposes (cooking, drinking, bathing, etc.) water is required every day. This domestic demand creates additional pressure on operating tube wells year-round thereby put tension on gender-based preference bias. In the case of groundwater utilization, gender issue reflects differently where males are mostly responsible for agricultural production water and females are responsible for domestic water. Production purpose is related to mainly irrigation for agricultural crop production and domestic purpose is related to drinking, cooking, cleaning, bathing, etc. Usually, females got responsibility for fetching water hence they preferred to have nearby sources of domestic water supply.
Research on gender and water relationships has largely focused on the division of tasks and labor between men and women, rights and access to water and women's participation in decision making through their involvement in water management organizations (Sultana, 2007) but gender relations are influenced by not just direct resource use/control/access and the implications of different types of waters, but also by the ideological constructs of masculinity/femininity, which can work in iterative ways to influence how people relate different kinds of water (Sultana, 2009). The issue of gender in the water sector does not simply involve access to water moreover it involves questions of rights, responsibilities, and participation (equal participation by men and women both) at all levels (Nahar, 2002). A good number previous studies integrated at national and international levels based on gender-water relationship and the contribution of some researchers like Nahar (2002), Sultana (2007 and 2009), Faisal and Kabir (2005), Hussain (2007), Zwarteveen (2009 and 2016), Hoek et al. (1999), Velis et al. (2017), Urfels, et al. (2020) Rahman et al. (2020), have enriched gender-water relationship studies in Bangladesh elsewhere. From the earlier studies it is clear that in most societies, women and girls collect every liter of water for cooking, bathing, cleaning, maintaining health and hygiene, raising small livestock, and growing food. The distinction in using and managing water and includes how water is collected depends on income/social class, location of the water source, time of the day, and religious/cultural factors (Faisal and Kabir, 2005). Rights to water are less fixed and more prone to be contested at various levels and in different socio-legal domains than rights to other natural resources (Ahlers and Zwarteveen, 2009). While making large contributions to irrigated agriculture, women depend on, and benefit from, irrigation water in a variety of ways including water uses for domestic and livelihood purposes (Hussain, 2007; Velis et

al. 2017). Wahaj et al., (2012) report that women's role in the management of water resources has been increasingly acknowledged by development agencies, policymakers, national governments, and non-governmental organizations over the past decade and women's participation in water management are well documented, there is insufficient information, apart from some anecdotal evidence, on successful efforts to involve women in water projects. And these documenting gendered patterns of water work and water use, rights, and responsibilities is a first step in recognizing women's importance as water actors (Zwarteveen, 2016). The inclusion of users in operating and managing irrigation systems most often occurs through the organization of user's groups or associations (Zwarteveen, 2009) but as a major group of stakeholders, women are unable to effectively participate in these processes due to certain widespread constraints like culturally determined inhibitions to their participation in public activities; their resulting lack of skills and experience in public participation and leadership and management activities (Nahar, 2002). Therefore, this article reviews relevant literature on groundwater development status and its management aspects across gender. The study presents the availability of groundwater from various institutional sources in the selected locations, and determine the potential priorities of groundwater utilization by gender. Finally, it identifies the groundwater utilization barriers and proposes specific solutions to overcome them.

2. Literature Review

2.1 Groundwater Development in Bangladesh

The first groundwater development project was initiated under Bangladesh Agricultural Development Corporation (previously EPADC, East Pakistan Agricultural Development Corporation) in 1962, the Barind's Integrated Area Development Project (BIADP) in Dinajpur district under NW region (Dey et al., 2015). During the post-liberation period, the contribution of groundwater has increased from 41% to 79% in 2012-2013 (Qureshi et al., 2015). Presently, Barind Multipurpose Development Authority (BMDA), BADC (Bangladesh Agricultural Development Corporation), and RDA (Rural Development Academy) as public enterprises have installed thousands of DTWs (Deep Tubewells) in Barind area of NW region. In addition, quite a large number of STWs (Shallow Tube-well) have been installed in this region by private initiatives (Ahmad et al., 2008). Thus, over 97% of the total area uses groundwater irrigation (Majid et al., 2019). Zahid and Ahmed (2005) state that about 75 percent of cultivated land is irrigated by groundwater and the remaining 25 percent by surface water. Of the abstracted groundwater, about 70-90 percent is used for agricultural purposes and the rest for drinking and other water supplies. High rates of pumping for irrigation and other uses from the shallow aquifers in coastal areas may result in widespread saltwater intrusion, downward leakage of arsenic concentrations, and the general degradation of water resources. The continuous decline of groundwater tables due to over-withdrawal has also been reported from some areas. International Water Management (2006) reports that the abstraction of groundwater for irrigation requirement was higher than the recharge, causing constrains for *boro* paddy cultivation, but the northern part has a suitability for further groundwater development to meet the requirement for *boro* paddy cultivation. Studies also have noted that careful management can avoid problems in over-exploitation of resources and environmental degradation of this area. Similar results were found in the study of Wahid et al. (2007) conducted in Teesta riverine and Mamunul et al. (2012) conducted in Padma riverine.

Another study of Dey et al. (2013) reveals a declining trend of groundwater table over the last 30 years (1981-2011). The district under severe depletion of groundwater was the Rajshahi district followed by Pabna, Bogra, Dinajpur, and Rangpur district. The magnitude of the decline in the groundwater table was found between -2.3 to -11.5m during the study period. Drying up of local water bodies and rivers was noted by almost everyone. A study of Imon and Ahmed

Published by Scientific *Research Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

(2013) found that about 2/3 of the area showed a gradual fall in the water level both in dry and wet seasons. Most of the remaining area, situated in the west, east, and southeast, experienced lowing of the water level either in the post-monsoon season or during the lean period. Only small areas in Shibganj and Gomastapur in the west and Naogaon in the east exhibited a rise in water level. The study of Mainuddin et al. (2014) by supporting the situation adds that lower groundwater levels in the pre-monsoon period have meant a shift towards less groundwater moving to streams and more water moving from streams; more water infiltrating through the land surface, with a probable reduction in surface runoff and reduced return flow to streams. Aquifers are losing water to most major streams. The exceptions appear to be above junctions of major rivers and/or in areas where the landscape is flattening. Another study from Aziz et al. (2015) reported that in Northwestern Bangladesh especially in Rajshahi district groundwater levels are dropping. Only two aquifers exist and in NW area shows effective aquifer thickness is shorter than South East portion. Groundwater recharge condition is very poor in Tanore, Godagari, Mohanpur, and Baghmara Upazilas and vulnerable for Boro rice i.e. irrigated rice. A crucial relationship remains between Boro production and groundwater depletion, so crop diversification or less water consuming crops can be an option for the study area. A recent groundwater dynamic study report shows that Rajshahi division reveals insignificantly decreasing groundwater extraction trend; the extraction volume increased from 7339 Mm3 to 6702 Mm3 during the period from 1985 to 2016, and Rangpur division shows significantly increasing trend (4192 to 4986 Mm3 during 1985–2016) of groundwater extraction. For the whole NW region, groundwater extraction volume shows insignificantly increasing trend (11536 Mm3 to 11684 Mm3; 1.28%) (Rahman et al., 2020).

2.2 Groundwater Management

Dey et al. (2006) postulate that the economic benefits that the country can achieve if improved irrigation management is followed in Bangladesh. Proper irrigation water management means that water should arrive at the right place, at the right time, with the required volume and with minimum loss. It is estimated that the government of Bangladesh is to spend only an amount of US$1.74 million for the successful implementation of proper irrigation and other management activities, when in total an amount of US$1,344.26 million may be thus saved and added annually in the economy of Bangladesh. A study of Wichelns and Oster (2006) confesses the same result and suggests that irrigation should be discontinued in some areas and water should be re-allocated to nonagricultural uses. Another study of Droogersa et al. (2010) advances that water managers and policymakers need accurate estimates of real (actual) irrigation applications for effective monitoring of irrigation and efficient irrigation management. They identified three main strategies by which agricultural water management can deal with these large trade-offs: a) improving water management practices on agricultural lands, b) better linkage with the management of downstream aquatic ecosystems, and c) paying more attention to how water can be managed to create multifunctional agro-ecosystems. They suggested if ecological landscape processes are better understood the values of ecosystem services other than food production are also recognized. Qureshi et al. (2015) noted that the policy available in Bangladesh over groundwater focus so far has been largely on “resource development”, and not on “resource management”. They suggested that attention must be given to the development and management of surface water resources to ease pressure on groundwater. In addition to supply-side solutions, water demand will also need to be curtailed by increasing water use efficiency through the adoption of water-conserving management practices, for example, reduced tillage and raised bed planting, and the right choice of appropriate crops. Therefore, cropping patterns need to be rationalized – starting with the promotion of feasible alternatives to *boro*-considering water availability and the sustainability of aquifers. On the contrary, a study of Chowdhury and Rasul (2011) argues that

 Published by Scientific *Research Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

the governance of water resources in Bangladesh is biased towards structural solutions of flood control and irrigation through a centralized approach that ignores the other uses of water such as drinking and sanitation, fisheries, navigation, and ecology, and ignores the costs borne by the rural poor. Often, the access to water resources and the costs and benefits of water resources project is distributed unequally. While the rich get more access to water resources, the poor bear the cost. Successful water resource management involves balancing the needs of a wide range of water-users along with the needs of the environment. Water resource management should not be based on economic benefit alone. Social, environmental, and ecological aspects should be considered in the process of identification, planning, implementation, operation, and maintenance of water management projects. To ensure sustainable water management, Rasul and Chowdhury (2010) propose a framework for promoting equity in water management and preserving the environment. Dey et al. (2017) advance that efficient irrigation management practices, such as low water demanding high-value crops, volumetric water charging system, wet and dry irrigation system, etc. can be introduced widely to reduce excessive withdrawal of groundwater. The efficiency of existing water-lifting devices including shallow tube wells and deep tube wells can be enhanced for increasing the command area and discouraged for the new installation of tube well. Bangladesh has recently experienced moderate rainfall during September-October. If the *boro* rice transplantation is completed by November, *boro* cultivation may benefit from late-monsoon rains and place less pressure on groundwater resources.

2.3 Gender in Groundwater Management

A study from Faisal and Kabir (2005) postulates the distinction in using and managing water and includes how water is collected depends on income/social class, location of the water source, time of the day, and religious/cultural factors. The time spent on water collection imposes significant opportunity costs like loss of income and education opportunities. There is very little participation of women in agricultural water management as 'right to water' is perceived as linked with 'right to land', over which women have little control. These hardships and deprivations are fundamentally caused by the lack of a number of factors: awareness, education, access to resources, empowerment, and institutional support. Sultana (2009) adds that gender relations are influenced by not just direct resource use/control/access and the implications of different types of waters, but also by the ideological constructs of masculinity/femininity, which can work in iterative ways to influence how people relate to different kinds of water. Gender–water relations are not just intersected by social axes, as generally argued by feminist scholars, but also by ecological change and spatial relations vis-a`-vis water, where simultaneously socialized, ecologized, spatialized, and embodied subjectivities are produced and negotiated in everyday practices. Ahlers and Zwarteveen (2009) report that rights to water are less fixed and more prone to be contested at various levels and in different socio-legal domains than rights to other natural resources. Water reforms articulate with wider political-economic structures and historical dynamics characterized by new ways of capitalist expansion. Another study from Zwarteveen (2009) verifies that the inclusion of users in operating and managing irrigation systems most often occurs through the organization of user's groups or associations. In most irrigation cases, women appear to be almost absent from those groups. This is partly because membership is often confined to one member of each irrigating household, either the official landholder or the 'head' of the household. Both criteria apply to men far more often than to women; the only women who can potentially participate in water users' groups are either widows or single mothers with no adult male living in the household. Hussain (2007) explores that while making large contributions to irrigated agriculture, women depend on, and benefit from, irrigation water in a variety of ways including water uses for domestic and livelihood purposes. Designing the irrigation infrastructure

Published by Scientific *Research Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

such that the irrigation systems become multiple-use systems can enhance the benefits of investments in irrigation for the poor women. It's also supported by Wahaj et al. (2012) report that women's role in the management of water resources has been increasingly acknowledged by development agencies, policymakers, national governments, and non-governmental organizations over the past decade. Programs and projects that include supporting components such as capacity-development, access to capital, and awareness-raising achieve better results in encouraging women's participation and improving their livelihoods. One of the major findings of the study was although the problems and issues in women's participation in water management are well documented, there is insufficient information, apart from some anecdotal evidence, on successful efforts to involve women in water projects. But Zwarteveen (2016) argues that documenting gendered patterns of water work and water use, rights, and responsibilities is a first step in recognizing women's importance as water actors. And she also added that irrigation came to be a masculine domain as a consequence of engineering becoming a man's profession. Irrigation texts do not explicitly exclude women, but professional irrigation identity and men came to belong to each other at symbolic and metaphoric levels.
Nevertheless, Nahar (2002) verifies that the issue of gender in the water sector does not simply involve access to water. It involves questions of rights, responsibilities, and participation (equal participation by men and women both) at all levels. When women are not encouraged to participate in water management, they are simultaneously de-linked from the urgent effort to protect these vital natural resources. However, as a major group of stakeholders, women are unable to effectively participate in these processes due to certain widespread constraints. These include culturally determined inhibitions to their participation in public activities; their resulting lack of skills and experience in public participation and in leadership and management activities.

3. Materials and Method

3.1 Study Area

To explore the assessment of gender involvement in groundwater utilization in Northwestern Bangladesh, Rajshahi and Chapainawabgonj district was selected because the selected districts are identified as groundwater depleted area (Palash et al. 2019). Following Figure 1 presents the maps of the selected Upazila.

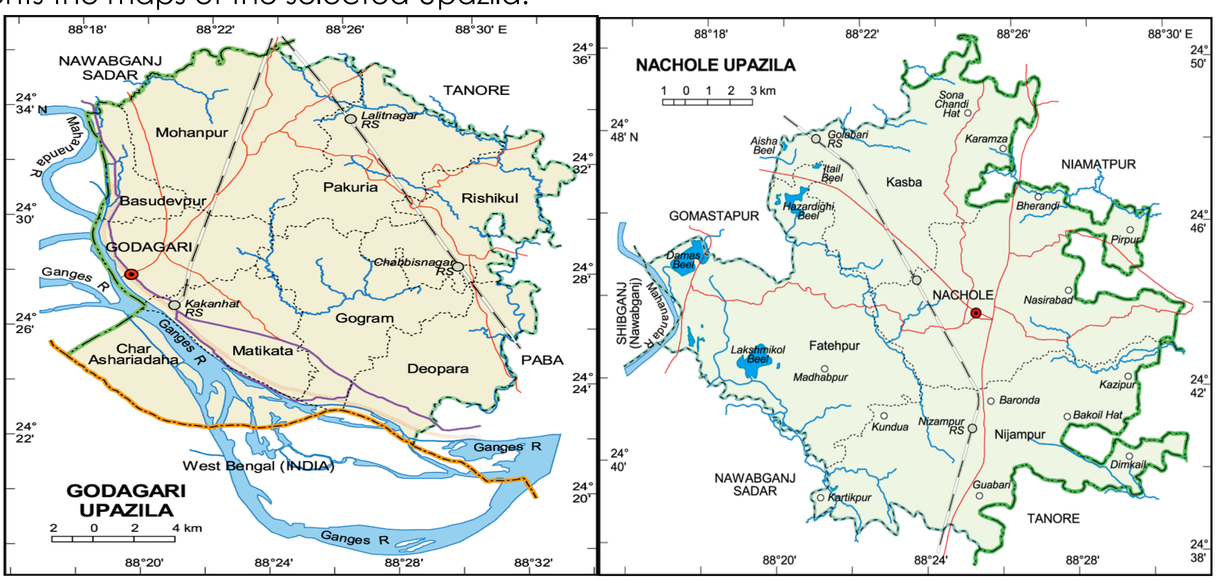

Figure 1: Study area (Godagari and Nacgole Upazila)

Source: LGED, Bangladesh

All the rivers and canals of these areas become dry during the dry season and make the people completely dependent on groundwater (Shahid 2008; Shahid and Behrawan 2008). In the beginning, overall information on socio-demography, total area, cropland, riverine area, irrigated area, cropping pattern, irrigation means/methods were collected. Based on preliminary information, three villages from each location were selected namely Ishoripur, Nimghutu and Fulbari from Godagari Upazila (geographical coordinates are 24° 28' 0" North, 88° 20' 0" East) of Rajshahi district and Ajhoir, Belpukur and Paikura from Nachole Upazila (24.7292° North 88.4194° East) of Chapainawabgonj district for empirical investigation. The majority of the people of the selected villages are dependent on farming.

3.2 Data Collection

With the help of the Sub Assistant Agriculture Officer (SAAO), a list of farmers was prepared from the selected villages mostly who grow *Rabi* (dry season) crops. A total of 60 households were interviewed in which 28 from Godagari and 32 from Nachole Upazila by using a simple random sampling technique. In fact, an equal number for households were interviewed in each sub-district, however, four samples of Godagari Upazila could not be used due to the low quality of required information. Both males and females from the selected households were interviewed thus a total of 120 respondents were interviewed. Along with household surveys, Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) were performed, aimed at gathering in-depth information on groundwater utilization. A checklist was prepared for FGDs which were organized by gathering mixed groups (male and female) of ten to twelve participants at one place where discussions took place after the purpose of the research was explained to them. Issues were clarified and opinions elicited followed by discussion. The ultimate consensus and information were documented. The key informant under this study was selected purposively those are experienced and expertise in groundwater aspects. After selecting the key informants, they were interviewed through prepared guidelines to collect historical information.

3.3 Data Analysis

After collecting the required data, data were digitalized, classified, used coding, and then analyzed to accomplish the objectives of the study. Both descriptive and econometric analysis was adopted for data analysis. The descriptive method was followed as it is simple in the calculation, widely used, and easy to understand. Data analysis was done by using Microsoft Excel and Statistical Package for Social Science (SPSS) version 20. The logistic regression model was adopted for determining the gender-based groundwater utilization priorities or preferences.

3.3.1 Specification of Econometric Analysis

To identify the gender-based priority of groundwater utilization, a logistic regression econometric model has been adopted for crop irrigation and domestic purpose. Logistic regression is used widely to examine and describe the relationship between a binary response variable (jointly decided or alone) and a set of predictor variables (Fitzmaurice and Laird, 2001). In order to explain the behavior of a binary (dichotomous) dependent variable, two scenarios were used—(i) respondent given higher priority than the average index score, and (ii) alternative- index value estimated below the average score. The response variable T_i is binary; that is, it can have only one of two possible outcomes, denoted as 1 (higher priority) and 0 (lower priority) based on the quantitative survey results. The outcome variable (T_i) was thought to be influenced by the independent variables (X_i). It was assumed that the model takes the form

$$Pr(Z = 1|B) = \varphi(B^1\delta) \quad (1)$$

where Pr denotes the probability, and φ is the function of the standard normal distribution. The parameter δ is typically estimated by maximum likelihood. It is also possible to motivate the logit model as a latent variable model. Suppose there exists an auxiliary random variable,

$$Z_i^* = \delta_k + \delta_k b_{ki} + w_i \quad (2)$$

where wi ~ N(0, 1). Then, Z can be viewed as an indicator of whether it is a latent variable and positive:

$$Z = 1_{\{Z^*>0\}} = \{1 \text{ if } Z^* > 0\} \text{ i.e } -w_i < B^i\delta, 0 \text{ otherwise.} \quad (3)$$

The main difference between logit and probit regression models is that the logit has slightly flatter tails, i.e., the normal or probit curve approaches the axes more quickly than the logit curve. Qualitatively, while logit and probit regression models give similar results, their parameter estimates are not directly comparable. The choice between the logit and probit models is largely one of convenience and convention since the substantive results are generally indistinguishable. Hence, an empirical logit model was developed to determine the factors that significantly increase the probability of giving higher priority in using groundwater for irrigation or domestic purpose.

$$T_i = \alpha_0 + \beta_i X_i + \cdots + e_i \quad (4)$$

where

Ti = Crop irrigation/domestic use is given higher priority in utilizing groundwater, α = Intercept, X_i = Explanatory variables, β_i = Coefficient of determinants, and e_i = Error term.

The explanatory variables considered in the logit model are as follows-

X_1 = Age of respondent (years), X_2= Gender (male and female respondents), X_3 = Year of schooling (years), X_4=Working members involve in agriculture- number, X_5 = Farm experience (years), X_6 = Farm size (decimal), X_7 =Time spent for water collection- hours, X_8 = Participation on water management training program- 1 or 0 (1= yes, 0=no), X_9 = Household income (Taka).

Through this logistic regression model, it is expected to identify the determinants of how the male and female prioritize their needs in utilizing groundwater. Generally, it is argued that male gives higher priority to irrigation use while female gives more value for domestic uses. This logistic regression was adopted to validate the general argument of using the preference of groundwater.

4. Results and Discussion

4.1 Groundwater Sources

The principal purpose of using groundwater is for agriculture and domestic work. Agricultural use of groundwater is mainly in irrigation purpose and domestic use is related to drinking, washing, cooking, cleaning, and household purpose. For the purpose of drinking and other household work, the people commonly relied on tube well or hand pump water. The implementation of the tube well is very costly in the study area and for most people, it seems luxurious. So, they rely on different sources for domestic water and sometimes installed tube well jointly/collectively. To describe the situation, FGD participant stated that:

"*In our area tube well installation is very expensive and most of us do not have the ability to install the tube well. So, to meet the domestic water demand about 20 households from our area decided to install a tube well and thus we are having water for our households.*"

There are mainly four kinds of domestic water sources in the study area, only 23% of surveyed households had own/personal tube well and rest depended on different water sources like BMDA piped supply (39%), community tube well (33%) and union *Parishad* (a local government institute) tube wells (5%) based on distance favorable to households (Figure 2).

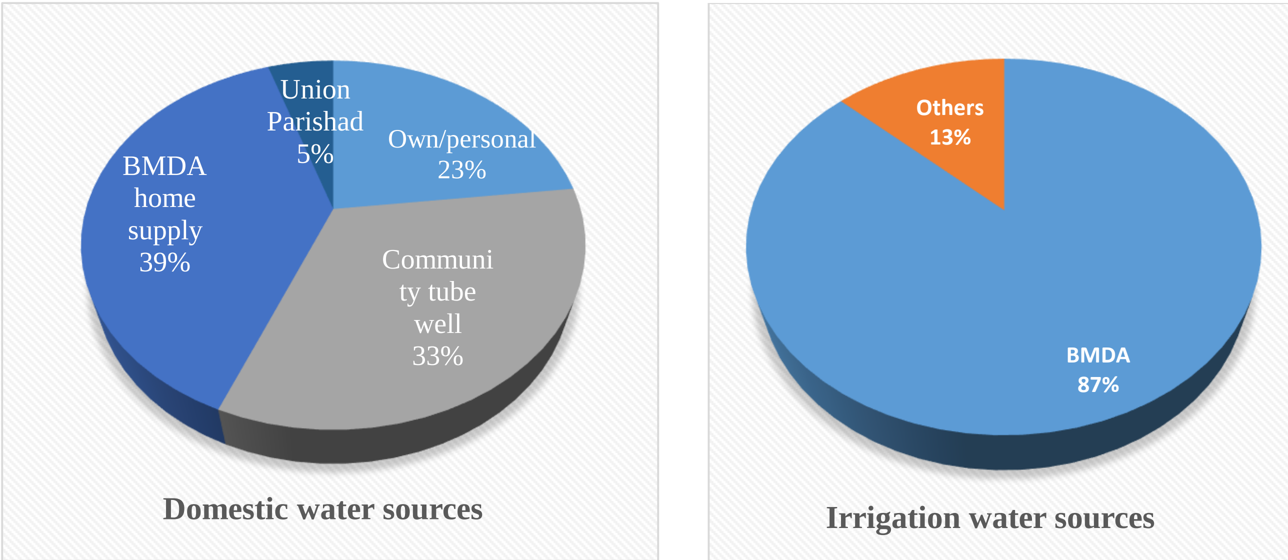

Figure 2: Groundwater Sources for domestic and irrigation purposes

In the study area, due to the high installation cost of tube well and water pump, most of the surveyed households had no possession of a personal irrigation pump, and most of the cases an entire village depended on one or two water sources for irrigation. For irrigation, most of the households relied on BMDA deep tube well and very few of them had their own irrigation pump. The reason for collecting water from the BMDA tube well is that it requires lower cost and in some areas, there were no other alternatives. It is revealed from the FGD discussion that "*As irrigation is very costly and irrigation pump installation is way much costly, so we depend on BMDA deep tube well for irrigation water.*" Regarding irrigation cost- FGD participant reported that "*We actually do not look for other alternatives because BMDA's water is less costly.*"
In fact, due to the emergence of BMDA, the other overall situation has changed as farmers can now grow more crops which were not possible earlier. The FGD participants reported that "*About 20 or 30 years before, we only depended on rain-fed crop cultivation as groundwater irrigation systems were unavailable and even many of us had no idea about groundwater extraction. At present we could grow so many dry season crops due to groundwater development particularly BMDA tube wells.*"

4.2 Gender in Groundwater User Groups

It has been found from different research that males and females play different roles and have different impacts on groundwater utilization. It involves questions of rights, responsibilities, and participation at all levels. Even National Water Policy (1998) emphasized equal participation of male and female in water resources management. "*To develop a state of knowledge and capability that will enable the country to design future water resources management plans by itself with economic efficiency, gender equity, social justice, and environmental awareness to facilitate achievement to the water management objectives through broad public participation.*" (National Water policy, 1998).
Groundwater is mostly used in two purposes, households and irrigation. Female collect water for domestic and male uses water for irrigation purpose. Almost in all the households, female collect water for household purposes, about 97% of household water were collected by female and the remaining 3% water was collected by the male (Figure 3). In case of irrigation, about 9% water was managed by female and the remaining 91% was managed by the male (Figure

Published by Scientific *Research Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

3) as there is very little participation of women in agricultural water management as 'right to water' is perceived as linked with 'right to land', over which women have little control. These lead to limited participation in groundwater irrigation management by female and thereby their preferences also reported at a lower level compared to the male counterpart.

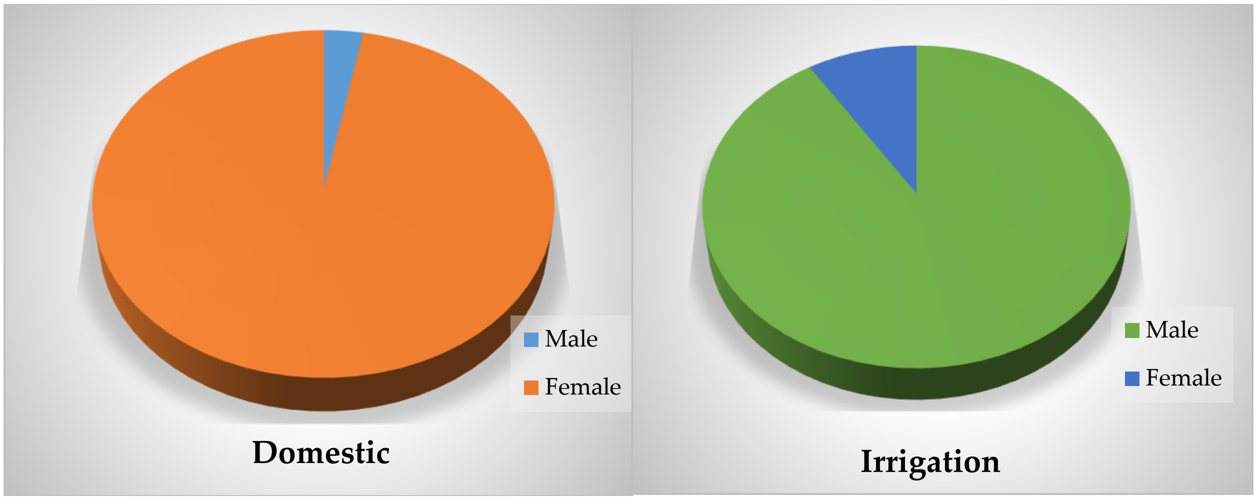

Figure 3: Contribution of gender in water collection (Domestic and irrigation)

4.3 Determinants of Groundwater Utilization Priority

As groundwater is scarce in the study villages, hence the priority of using groundwater is crucial for livelihood and food security. Groundwater is used for crop production and household activities- that have given different priorities by males and females. Whereas groundwater is mostly used for production purposes (irrigation) and domestic purpose, among them, the first one is related to economy and last one to health and safety, so all the factors are not the same for both purposes but there are some common factors and others are different. It is the hypothesis that male gives higher priority of irrigation use while female gives more value of domestic uses. To test the hypothesis a logistic regression model was fitted. The model contains 9 independent variables, as listed in Table 3. The full model containing all predictors was statistically significant for irrigation purposes—Chi-square (5, N = 120) = 20.915, $p < 0.005$—indicating that the model was able to distinguish between who gives high priority and those who do not. The model as a whole explained between 50% (Cox and Snell R square) and 35.3% (Nagelkerke R square) of the variance in priority, and correctly classified 91.59% of cases. Furthermore, the log-likelihood function (52.422) and the proportions of samples correctly predicted for their likely status in prioritizing groundwater decisions both indicate a good fit of the equation. It can be seen from Table 3 that five explanatory variables, i.e., age, sex, education, time spent for water management/collection, and household earning, had positive significant influences on the application of groundwater for crop production. By far, the greater predictor of irrigation water used is the "household income"—its odds ratio of 1.00 indicates that, in households with higher income, the likelihood of irrigation priority is about 1 times more than those with a lowered level of income, controlling for all other factors in the model. It is apparent that age, gender (sex), education, and household income found to be statistically significant at below 10% level of significance and the said explanatory variables are reported a positive association with utilization of groundwater for crop production. Similarly, time allocation of groundwater management/collection found to be below 1% level of significance and had a positive association with groundwater utilization.

Similarly, the results of logistic regression for domestic purpose shows that The full model containing all predictors was statistically significant for irrigation purpose—Chi-square (5, N =

Published by Scientific *Research Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

120) = 17.431, p < 0.005—indicating that the model was able to distinguish between who gives high priority for domestic use and those who do not. The model as a whole explained between 50% (Cox and Snell R square) and 19.1% (Nagelkerke R square) of the variance in priority, and correctly classified 70.833% of cases. Furthermore, the log-likelihood function (129.175) and the proportions of samples correctly predicted for their likely status in prioritizing groundwater utilization decisions both indicate a good fit of the equation.

It is apparent that four explanatory variables, i.e., sex, education, time spent for water management/collection, and training on water management, were statistically significant positive influences regarding utilization of groundwater for domestic purposes. By far, the strongest predictor of irrigation water used is the "sex"—its odds ratio of 8.01 indicates that the likelihood of domestic use priority is about 8 times more for females than that of males, controlling for all other factors in the model. It is apparent that gender (sex), education, and training on water management found to be statistically significant at below 10% level of significance and the said explanatory variables are reported a positive association with utilization of groundwater for domestic utilization. However, time allocation of groundwater management/collection found to be below 1% level of significance and had a positive association with groundwater utilization for domestic purposes. The odd ratio also estimated at 4.85, implies the likelihood of domestic use prioritized about 5 times more by female participants than that of males.

Table: 3 Results of logistic regression analysis for groundwater utilization for irrigation and domestic purposes

Variables	Irrigation purpose			Domestic purpose		
	Stad. Error	OR	Sig	Stad. Error	OR	Sig
Age	.038	.938	.098*	.027	.977	.388
Sex	1.752	.052	.092*	1.094	8.014	.057*
Education (year of schooling)	.103	.825	.061*	.056	.904	.071*
Farm experience (year)	.054	1.077	.169	.031	.982	.571
Working member in HHs	.639	.903	.874	.361	.623	.189
Farm size (decimal)	.004	.995	.184	.001	.999	.298
Time spent on water collection	1.084	.037	.002***	.723	4.848	.029**
Training on water management	.545	1.543	.426	.366	.502	.060*
HHs income	.000	1.000	.052*	.000	1.000	.288
Constant	3.810	52261.716	.004***	2.220	.112	.325
Log-Likelihood	52.422			129.175		
Cox and Snell R Square	0.161			0.135		
Nagelkerke R Square	0.350			0.191		
Chi-Square	20.915035		0.013**	17.431		0.042**
Overall Model Predicted (%)	91.596			70.833		

Dependent Variable: Priority of irrigation water utilization and priority of domestic water utilization; OR- Odd Ration
*, **, *** indicates significant at the level of 10%, 5% and 1% respectively.

4.4 Problems and Constraints faced in Groundwater Utilization

The question is, who faces more or most problems and constrains regarding groundwater utilization? Is it males who collect water for irrigation purpose or females who fetch water for domestic purpose or male and female equally faces the problems and constraints on groundwater utilization? It is not an easy answer to find as males and females have different purposes for using groundwater. The study result is shown in Figure 3. It is evident from Figure 3 that both male and female respondents reported that they faced more problems and constrains compared to their counterparts. Male respondents exclusively (81.4%) reported that they faced more problems and constrains during groundwater utilization but from the female's view the percentage was very close (50% female and 44.4% male). Only a few respondents opined that both males and females equally faced problems and constraints.

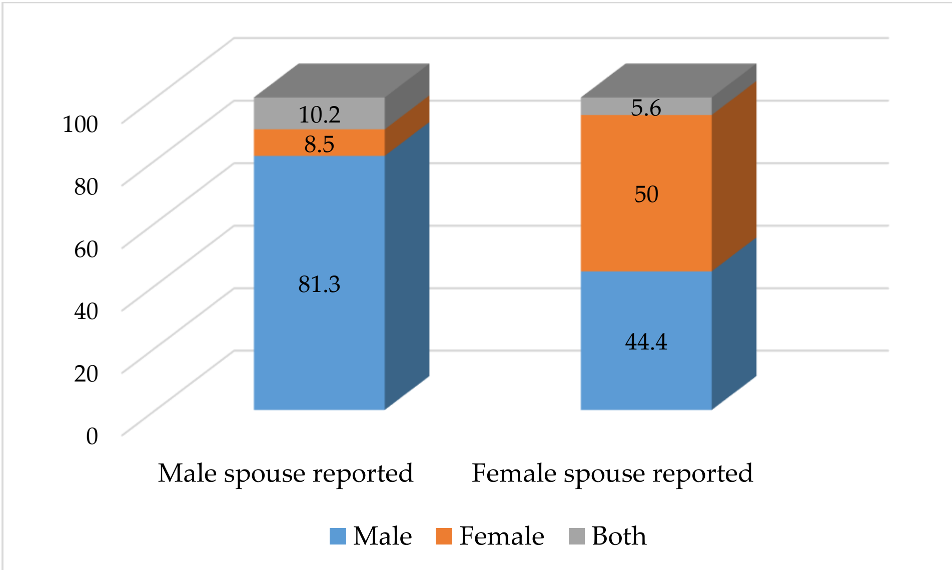

Figure 3: Problems and constraints faced in groundwater utilization

While delineating major problems both for domestic and irrigation water, a total of 7 problems for domestic uses and 11 problems for irrigation water were identified and ranked. The foremost problem was insufficient water supply that was ranked first regarding domestic water uses. Followed by slippery/risky of water collection point (2nd), load-shedding (3rd), fetching water is a laborious task (4th); unsafe for women in fetching water at night (5th); limited sources and crowd (6th), and required more times in fetching water (7th). On the other hand, problems and constrains regarding irrigation water were- maintaining serial for irrigating plots (1st), too much time consuming (2nd), unavailability of water in the peak season (3rd), load-shedding (4th), the farmer had to bear repairing cost (5th), inadequate drainage system (6th), biased management system (7th), irrigation cost is high (8th) and conflict between operator and water buyers (9th).

4.5 Proposed Solution by the Respondents

The bottom-up approach is always better than a top-down approach because those who are living with the problems know the best solution than that of others. Keeping this view in mind, at the end of every interview, each respondent was requested to mention some solutions based on the problems and constraints they mentioned before. For better understanding, these proposed solutions were ranked and presented in Table 4. The prime demand of the people in the study area was to manage alternative water sources for irrigation purposes only so that the pressure on groundwater can be minimized. The second most prioritized demand was full-time electricity supply during the irrigation period at least for the running irrigation pump. The third and fourth demand was for the implementation of more tube wells and irrigation water pump to reduce pressure and also to save valuable time. Some of the problems can be resolved within a day, just need willingness and cooperation from the supplier authority and others need more preparation and time.

Published by Scientific *Research Initiative*, 3112 Jarvis Ave, Warren, MI 48091, USA

Table 4: Proposed solutions on groundwater-related constraints

Proposed solution	Frequency	Rank
Identify alternative water source for irrigation including surface water	79	1
Full-time electricity supply during the irrigation period	72	2
Implementation of more tube wells or piped water for domestic use	63	3
Implementation of more water pump/deep tube well for irrigation purpose	57	4
Ensure adequate and timely water supply	56	5
Water cost should be reduced	53	6
Manage surface water/water from the river for irrigation	48	7
Tube well repairing cost should be borne by the suppliers	47	8

5. Conclusion

Groundwater irrigation has contributed significantly to increase the production and yield of cereal and non-cereal crops over the years particularly in northwest Bangladesh. In fact, intensive groundwater development has occurred in northwest regions and that are used for crop production and household activities. Among different groundwater service providers, Barind Multipurpose Development Authority operated tube wells have been dominating the in study villages and supply both irrigation and domestic water. The availability of groundwater has changed the livelihoods of the northwest people of Bangladesh, particularly in the study villages. However, excessive extraction of groundwater causes water table depletion in some areas which pressure on the conducive use of groundwater for irrigation and households. Groundwater is crucial for crop production and domestic uses but the priority varies across gender due to their close engagement. Female has given greater preference on domestic uses of groundwater while the male has a preference for crop irrigation. One of the major factors of preference variation is that female has to spent a good amount of time in fetching water for domestic uses. Water management policies should consider these utilization preferences to avoid extra burden on women in fetching water from away. The study suggests the installation of more tube wells for domestic uses through a public-private partnership which will reduce the extra burden of women in fetching water. Alternative water sources like river water can be brought through a channel for irrigation use. Better institutional arrangement of groundwater availability for crop production and domestic uses might benefit from ensuring food security and health benefits.

The present study was carried out in two districts of northwest Bangladesh, and the findings were generated based on 60 randomly selected households and focus group discussions. These findings may not be generalized for the entire population of the country. Future research can be carried out on a large scale across the country to document diversity.

Funding: This work was undertaken in collaboration with CSIRO and contributes to the South Asia Sustainable Development Investment Portfolio funded by the Department of Foreign Affairs and Trade (DFAT) of the Government of Australia.

Author Contributions: Md Asaduzzaman prepares the draft of the paper, Md. Wakilur Rahman provides insights into the analytical approach, Md. Salauddin Palash contributes to data analysis, Shokhrukh –Mirzo Jalilov provides extensive feedback on the draft.

Conflict of interest: The authors declare no conflict of interest.

REFERENCES

Ahlers, R., and Zwarteveen, M. (2009). The Water Question in Feminism: Water Control and Gender Inequities in a Neoliberal Era, *Gender, Place, and Culture*, 16(4):409-426. doi.org/10.1080/09663690903003926.

Ahmad, E., Hossain, A.F.M., and Hassan, M. (2008). Water Scarcity, Global Changes, and Groundwater Management Responses in the Context of the Northwest Region of Bangladesh, 2008. Viewed 30 December 2019, <www.groundwaterconference. uci.edu/files/Chapter2/2008_conf_Ahmad,%20E.pdf.>

Amin, S., Rai, A.S., Topa, G. (2003). Does microcredit reach the poor and vulnerable? Evidence from northern Bangladesh, *Journal of Development Economics,* 70(1): 59-82. https://doi.org/10.1016/S0304-3878(02)00087-1.

Aziz, M.A., Majumder, M.A.K., Kabir, M.S., Hossain, M.I., Rahman, N.M.F., Rahman, F., and Hosen, S. (2015). Groundwater Depletion with Expansion of irrigation in Barind Tract: A Case Study of Rajshahi District of Bangladesh, *International Journal of Geology, Agriculture and Environmental Science*, 3(1): 32-28.

BBS (2019). Statistical yearbook of Bangladesh, Bangladesh Bureau of Statistics, Ministry of Planning, Bangladesh.

Chowdhury, A.K.M.J.U. and Rasul, G. (2011). Equity and Social Justice in Water Resource Governance: The Case of Bangladesh, *South Asian Water Studies*, 2(2): 45-58.

Dey, N.C., Bala, S. K., Islam, A. K., Saha, R., Shopan, A. A., and Rashid, A. (2013). "Sustainability of Groundwater Use for Irrigation in Northwest Bangladesh". National Food Policy Capacity Strengthening Programme (NFPCSP) Phase II.

Dey, N.C., Bala, S.K., and Hayakawa, S. (2006). Assessing the Economic Benefits of Improved Irrigation Management: A Case Study of Bangladesh, *Water policy*, 8(6): 573-584. https://doi.org/10.2166/wp.2006.058.

Dey, N.C., Bala, S.K., Islam, A.K., Saha, R., Shopan, A.A., and Rashid, A. (2015). Environmental and Economic Sustainability of Groundwater for Irrigation: Implications for Ensuring Food Security in the Northwest Region of Bangladesh.

Dey, N.C., Saha, R., Parvez, M., Bala, S.K., Islam, A.S., Paul, K., and Hossain, M. (2017). Sustainability of Groundwater Use for Irrigation of Dry-season Crops in Northwest Bangladesh, *Groundwater for Sustainable Development*, 4(2017): 66-77. https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2 Fj.gsd.2017.02.001.

Droogersa, P., Immerzeela, W.W., and Lorite, I.J. (2010). Estimating Actual Irrigation Application by Remotely Sensed Evapotranspiration Observations, *Agricultural Water Management*, 97(9): 1351-1359.

Faisal, I.M., and Kabir, M.R. (2005). An Analysis of Gender–Water Nexus in Rural Bangladesh, *Journal of Developing Societies*, 21 (2): 175-194. https://doi.org/10.1177%2F0169796X05054623.

Fitzmaurice, G.M., and Laird, N.M. (2001). Multivariate Analysis: Discrete Variables (Logistic Regression). In International Encyclopedia of the Social & Behavioral Sciences; Elsevier: Amsterdam, The Netherlands, 2001; pp. 10221–10228. doi.org/10.1016/B0-08-043076-7/00476-9

Hoek, W.V.D., Flemming, K., and Waqar A. J. (1999). Domestic Use of Irrigation Water: Health Hazard or Opportunity?, International Journal of Water Resources Development, Vol.15 No.1-2, pp.107-119, DOI:10.1080/07900629948961 https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1002%2Fird.295

Hussain, I. (2007). Understanding Gender and Diversity Dimensions of Irrigation Management for Pro-Poor Interventions, *Irrigation, and Drainage*, 56(1): 59-82.

Imon, A.H.M.R., and Ahmed, M. (2013). Water Level Trend in the Barind Area, *Malaysian Journal of Mathematical Science*, 7(1): 1-15.

International Water Management (2006). Project Brief on Groundwater Model Study for Deep Tube Well Installation Project on Barind Area, Institute of Water Modeling, Dhaka.

Mainuddin, M., Kirby, M., Walker, G., Connor, J. (2014). Sustaining water resources for food security in Bangladesh. http://hdl.handle.net/102.100.100/93825?index=1.

Manamul, A.H.M., Jahan, C.S., Mazumder, Q.H., Nawaz, S.M.S., Mridha, G.C., Mamud, P. and Adham, M.I. (2012). Hydrological Condition and Assessment of Groundwater Resource Using Visual Mudflow Modeling, Rajshahi City Aquifer, Bangladesh Journal Geographic Society, 79(1): 77-84.

Mojid, M.A., Parvez, M.F., Mainuddin, M., and Hodgson, G. (2019). Water Table Trend-A Sustainability Status of Groundwater Development in North-West Bangladesh, *Water Resources Management, Policy and Governance*, 11(6): 1182. doi:10.3390/w11061182.

Nahar, B.S. (2002). Gender, Water, and Poverty; Experiences from Water Resource Management Projects in Bangladesh.
National Water Policy (1998). Ministry of Water Resources, Government of the People's Republic of Bangladesh.
Palash, M.S., Rahman, M.W., Amin, M.R., Mainuddin, M, and Jalilov, S. (2019). Water stress effect on the factors of production of irrigated rice in Northwest regions of Bangladesh, *Bangladesh Journal of Agricultural Economics,* 40(1&2): 43-56.
Qureshi, A.S., Ahmed, Z.U., Krupnik, T.J. (2015). Groundwater Management in Bangladesh: An Analysis of Problems and Opportunities. DOI: 10.13140/2.1.2381.9040.
Rahman, M. W., Jahan, H. Palash, M. S., Mojid, M.A., Jalilov, S., and Mainuddin, M. (2020). Sustaining groundwater irrigation for food security in the Northwest Region of Bangladesh, Report submitted to the CSIRO, Australia on 21 June 2020.
Rahman, M.W., and Ahmed, R. (2008). Shallow tube well irrigation business in Bangladesh, Paper presented at Summary and Synthesis Workshop at Kathmandu, Nepal, March 20- 24, 2008.
Rahman, M.W., and Parvin, L. (2009). Impact of Irrigation on Food Security in Bangladesh for the Past Three Decades, *Journal of Water Resource and Protection*, I(3): 216-225. DOI: 10.4236/jwarp.2009.
Rahman, M.W., Palash, M.S., Jahan, H., Jalilov, S., and Mainuddin M. (2020). An Empirical Investigation of Men's Views of Women's Contribution to Farming in Northwest Bangladesh. Sustainability Vol. 12, 3521.
Rasul, G., and Chowdhury, A.K.M.J.U. (2010). Equity and Social Justice in Water Resource Management in Bangladesh, Gatekeeper 146.
Shahid, S. (2008). Spatial and temporal characteristics of droughts in the western part of Bangladesh, *Journal of Hydrological Process*, 21(13): 2235-2247. DOI: 10.1002/hyp.6820.
Shahid, S., and Behrawan, H. (2008). Drought risk assessment in the western part of Bangladesh, *Journal of Natural disaster*, 6(3): 391-413.
Sultana, F. (2007). Water, Water Everywhere, But Not a Drop to Drink: Pani Politics (Water Politics) in Rural Bangladesh, *International Feminist Journal of Politics*, 9(4): 492-502. https://doi.org/10.1080/14616740701607994.
Sultana, F. (2009). Fluid Lives: Subjectivities, Gender and Rural Bangladesh, *Gender, Place and Culture*, 16(4): 427-444. https://doi.org/10.1080/09663690903003942.
United Nations Conference on Sustainable Development (UNCSD), (2012). RIO+ 20- the future we want, Rio de Janerio, Brazil.
Urfels, A., McDonald, A.J., Krupnik, T.J., and van Oel, P.R. (2020) Drivers of groundwater utilization in water-limited rice production systems in Nepal, Water International, 45:1, 39-59, DOI: 10.1080/02508060.2019.1708172
Velis, M., Conti K.I. and Biermann, F. (2017). Groundwater and human development: synergies and trade-offs within the context of sustainable development goals, Sustain Sci (2017) 12:1007–1017. DOI 10.1007/s11625-017-0490-9
Wahaj, R., Hartl, M., Lubbock, R., Cleveringa, R., and Nepveu, A. (2012). Gender and Water, Securing Water for Improved Rural Livelihoods: The Multiple-uses System Approach.
Wahid, S.M., Babel, M.S., Gupta, A.D., and Clemente, R.S. (2007). Spatial Assessment of Groundwater Use Potential for Irrigation in Teesta Barrage Project in Bangladesh*,* *Hydrology Journal*, 15(2): 365-382.
WB (World Bank) (2016). Dynamics of rural growth in Bangladesh: Sustaining Poverty Reduction. Viewed 20 September 2019, < http://documents.worldbank.org/curated/en/2016/05/26377500/dynamics-rural-growth-bangladesh-sustainting-poverty-reduction>.
Wichelns, D., and Oster, J.D. (2006). Sustainable Irrigation is Necessary and Achievable, but Direct Costs and Environmental Impacts can be Sustainable, *Journal of Agricultural Water Management,* 86(1-2): 114-127.
World Bank, (2016). Better Inland Waterways Leading to More Domestic and Regional Connectivity. Bangladesh Regional Waterway Transport Project 1.
Zahid, A., and Ahmed, S.R.U. (2005). Groundwater Resources Development in Bangladesh: Contribution to Irrigation for Food Security and Constraints to Sustainability.https://econpapers.repec.org/scripts/redir.pf?u=http%3A%2F%2Fpublications.iwmi.org%2Fpdf%2FH039306.pdf;h=repec:iwt:bosers:h039306
Zwarteveen, M. (2009). Linking Women to the Main Canal: Gender and Irrigation Management, Gatekeeper 54.
Zwarteveen, M. (2016). Questioning Masculinities in Water, In M. Shah and P.S. Vijayshankar (Eds.), Water, Growing Understanding, Emerging Perspectives: Essays from Economic and Political Weekly (199-217), Hyderabad: Orient Blackswan.